GASTEROMYCETES OF AUSTRALASIA.

ii. A Revision of the Genus Tulostoma.

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(Plates xxxiii-xxxv.)

[Read 29th July, 1925.]

This paper is the second of a series dealing with the genera and species of the Australian and New Zealand Gasteromycetes. It is the intention of the writer to deal with all genera and species of this sub-class, revising the descriptions and presenting photographs when available, together with micro-photographs of salient microscopic characters. In addition it is intended to work out the development of one or more species of each genus (when material is available), and finally to rearrange the whole according to a modern system of classification. When completed, all these papers will be issued in book form. The author will gladly receive material for description and determination, especially any showing developmental stages of different species and genera of Gasteromycetes. Dr. J. B. Cleland, The University, Adelaide, has very generously lent the whole of his extensive collections, comprising more material than exists in the whole of the other herbaria of Australasia.

Members of the genus *Tulostoma* are found in practically every country throughout the world, but are most abundant in hot and sandy regions. They are characterized by the stipitate, two-layered peridium, which dehisces by an apical orifice, the long, frequently branched, septate capillitium and the coloured, continuous spores. They are usually found with the peridium alone projecting above the surface of the sand or other substratum in which they grow. This makes them difficult to observe, as owing to their inconspicuous colour they are readily overlooked. Immature plants are buried 5-6 cm. or more beneath the surface, and may be obtained only by carèful examination of the soil in the vicinity of mature plants.

Structure of the Mature Plant.

Peridium.—This consists of two layers, an exoperidium and an endoperidium. The exoperidium is usually fugacious, soon falling away, save at the base, where it persists as a thick toughened membrane enclosing the endoperidium in a cupulate structure. The former is perforated by the stipe, to which it may occasionally be attached, but usually it is free. In structure the exoperidium consists of somewhat loosely woven hyphae in which are embedded numerous particles of sand, earth or vegetable matter, according to the substratum in which the plant may happen to be growing. Occasionally it does not fall away, but persists as an investment surrounding the endoperidium; this was the principal character upon which was erected the species *T. adhaerens* Lloyd. In other species it is partly adherent, then giving a shaggy appearance

to the specimen by reason of the irregular appearance of the adhering particles, or it may consist of hyphae woven into little projections, which persist and give to the whole plant a verrucose appearance.

The endoperidium is in the nature of a thin, tough, papyraceous membrane enclosing the gleba; it is apically perforated by the so-called mouth, and basally attached to the stipe but separable from it. It consists of an outer intricately woven layer of hyphae of a diameter about half that of the capillitial threads. These hyphae are freely septate, hyaline, and not swollen at the septa. They may be somewhat even, when the endoperidium appears smooth, or may extend for some little distance as free hyphae, giving to the whole peridium a strongly sulcate or fibrillose appearance. Enclosed within this is a second thin layer of pseudoparenchymatous tissue, the cells of which are more or less isodiametric, and it is this layer which gives the endoperidium its toughness. Inside this second layer is a third arising directly from it, and from the free ends of the hyphae of which it is composed arise the threads of the capillitium.

The gleba consists of copious capillitial threads immixed with the abundant spores. The capillitium consists of very numerous long, branched, scantily septate threads. They are usually colourless, but may appear tinted, especially at the septa. The septa may be swollen to about twice the normal thickness, or not, and swollen and non-swollen septa are not infrequent in the same specimen. The ultimate branchlets are thinner than the main branches, and are rounded at their free ends. The spores are usually globose or subglobose, and average about 5 μ in diameter. They are all some shade of brown, and the epispore may be rough or smooth.

The spores are borne on clavate or cylindrical basidia, but instead of being produced apically, as is usual in the Gasteromycetes, they are borne laterally on short sterigmata. Frequently the sterigmata are detached with the spores and remain attached to them, when the spores are said to be "pedicellate" or "apiculate." It is extremely difficult to obtain basidia in other than very immature plants, for spore production is well advanced ere the plants appear on the surface.

Mouth.—This differs in certain species so that it serves as a good group character. Three distinct types may be recognized:—

(1) A circular, definite, erumpent-tubular mouth, characteristic of the type of the genus, *T. brumale*. Sometimes in this group the mouth is not circular, but elliptical and almost plane; this condition may arise as a result of weathering, for it is most frequently met with in old and weathered specimens.

(2) A definite, circular, umbonate mouth surrounded by a layer of hyphae arranged radially around it. This type is said to be fibrillose. In old specimens the fibrils frequently disappear, when the mouth is seen to resemble closely the first type.

(3) An indefinite plane or erumpent aperture. The orifice in this group appears simply as a rupture in the apex of the endoperidium.

(4) Other types of mouths are known. For example a species found in Brazil, *T. exasperatum*, has a raised mouth so resembling those termed fimbriate in the genus *Geaster*, etc., as to have this name applied to it.

Finally Lloyd (1906) mentions a group which may have several mouths in the same endoperidium. The writer has not seen any specimens he would consider to belong to this group.

Stipe.—This varies greatly in length and breadth, even in specimens of the same collection. It consists of an outer cortex, which is usually deciduous, and

an inner stipe proper, composed of pseudoparenchymatous tissue. The stipe is hollow and is invariably filled with a fibrous tissue, hence it is said to be "stuffed". The cortex usually falls away more or less completely, but may persist in the form of coarse scales, as in *T. australianum*. When it falls completely away the stipe is usually smooth, in which condition it often exhibits longitudinal striae. The colour varies according to age, but is by no means constant, even in the same collection. At the base is usually present a bulbous structure which may be hard and woody like the stem, or may consist solely of loosely interwoven mycelial tissue. This structure varies greatly in size and shape, and so is of slight importance to the systematist.

Systematic Position of the Genus.

In the most recent work (Fischer, 1900) the genus is placed in the family Tulostomataceae of the order Plectobasidiineae, containing the four genera *Tulostoma*, *Queletia*, *Battarrea* and *Sphaericeps*. Discussion on its true phylogenetic position will be deferred until such time as other related genera have been dealt with, and until certain details of development have been worked out.

Owing to the difficulty of procuring developmental stages, the life-cycle and development of any member of the genus has yet to be worked out. Bessey (1887) mentions the fact that the gleba matures underground, elongation of the stipe commencing only after this has been effected.

Schroeter (1887) has studied the development of spores and basidia in *T. brumale*, and was the first to point out that the spores were borne laterally on a basidium which, in this particular, resembles that of certain of the Uredinales, save that it is continuous, and not septate. No other work appears to have been undertaken with reference to development of members of the genus.

Specific Characters.

Some sixty species have been described; of these twenty have been recorded from Australia, but it is doubtful whether many of these are species, or merely forms of already described species.

Considerable confusion exists in the delimitation of species, and by certain workers the genus is considered to be the most difficult of any included in the Gasteromycetes. The writer believes this confusion to have arisen through the authors of various species fixing upon variable characters, such as shape, size and colour of the peridium, length and colour of the stipe, and degree of septation of the capillitium.

He has recently made a critical examination of some 200 plants of the species *T. poculatum* (the only species found in abundance in New Zealand), and has found that the peridium varies in size from 2 to 12 mm.; it may be perfectly smooth, or more or less covered with the adhering exoperidium; or may be pitted as in the so-called species *T. punctatum* Peck; it may be dingy white or dark brown in colour; and this colour may be spread over the whole peridium, or confined to a portion only. Each of these variations, supposing extremes only were examined, is sufficient to erect a "species" upon. That numerous species have been erected on such flimsy characters is very evident when the literature dealing with the genus is consulted. Owing to this variability it would be unwise to continue to erect species upon colour, roughness or otherwise of the peridium, or even upon size (unless very marked), for this too is by no means constant.

The difficulty is to decide what are fixed characters in such a variable genus; about half of the species which have been described to date cannot be separated on any recognizable character. Recently the writer has worked over various collections of this genus collected in Australia, Tasmania and New Zealand, endeavouring to arrange and describe the collections in such a manner that they would be readily recognized. When arranged according to the older ideas of classification, hopeless chaos resulted; mouth characters were sufficient to split the whole of the collections into three or four groups; drawings and photomicrographs of the capillitium of some ten species were compared, but no one species showed characters not present in others to a greater or less extent.

Finally all collections were treated as unknowns, and certain spore characters alone considered, when it was found possible to separate all into definite groups, as is shown in the artificial key. It became, then, a relatively simple matter to subdivide these groups by mouth characters, colour of the peridium, etc. Spore markings are the most constant of all characters present in the genus, being the least variable; they may readily be defined, and may equally readily be illustrated.

The writer finds that possession of a good equipment is a necessity if reliable results are to be obtained. Personally he uses apochromatic objectives, and does not hesitate to use the oil immersion when in doubt as to the markings on any spores. When apochromats are used good results cannot be expected unless a good condenser is used—the Abbé pattern is worthless for critical work. In addition, attention must be paid to proper correction for cover slip thickness and refractive index of the mountant, for these objectives are hypersensitive in this direction.

For temporary mounts the most suitable medium the writer has used is lactic acid solution, 50% acid in water. Spores are placed in this and heated to nearly boiling point of the solution, when all markings are readily seen, and pseudo-markings (such as folds due to shrinkage) disappear. For critical observations under the oil immersion, canada balsam mounts are desirable.

* Tulostoma Persoon.

Syn. Fungi, 1801, p. 139.—*Tylostoma* de Toni, Sacc. *Syll. Fung.*, vii, 1888, p. 60.

Peridium stipitate, globose to depressed-globose; consisting of an outer thin, usually fugacious exoperidium, and a thin, membranous, coloured or colourless, smooth or rough endoperidium; dehiscing by an apical orifice or mouth, which may be definite or indefinite, naked or fibrillose, erumpent-tubular, umbonate or plane.

Stipe inserted in a "socket" at base of endoperidium to which it is attached; woody, smooth or scaly, striate or not, concolorous throughout, stuffed; usually with a mycelial bulb at base.

Gleba of capillitium and spores, without sterile veins. Capillitium copious, consisting of numerous tinted or hyaline, very long, usually branched threads attached to the endoperidium, septate or not, septa inflated or not. Spores coloured, globose or subglobose, seldom angular, smooth or variously roughened.

Habitat.—Solitary, gregarious or caespitose on ground or more rarely on decaying wood.

Distribution.—World-wide; most plentiful in warm and sandy regions.

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* *Tulostoma*: This was the original spelling used by Persoon, and later by Fries. In *Sylloge Fungorum*, it was by de Toni arbitrarily changed to *Tylostoma*. This is contrary to the International Rules of Nomenclature, so the original spelling of the word must be retained.

Species may be divided into groups according to the mouth characters, but the writer has found it more convenient to make the initial division on spore characters, separating on mouth and peridial characters later.

The spores may be divided into three groups, as given in the key; these divisions are relative, but once seen the differences are readily recognized (see photomicrographs of spores).

All descriptions are original, save where otherwise stated, and have been drawn up from material examined by the writer. All photographs are original and have been taken by my friend Mr. H. Drake, of this laboratory. Their uniform excellence assists greatly in the illumination of characters imperfectly described in the specific descriptions.

The writer is indebted to Dr. J. B. Cleland, The University, Adelaide, for the loan of all collections of this genus in his herbarium; to Mr. L. Rodway, Government Botanist, Hobart, and Mr. C. C. Brittlebank, Plant Pathologist, Dept. of Agriculture, Melbourne, for the loan of specimens from their respective herbaria. Finally he would like to record his appreciation of the work undertaken by Mr. C. G. Lloyd, Cincinnati, Ohio. Mr. Lloyd has examined practically every historical specimen in the herbaria of Europe and America, and by the aid of critical notes and copious illustrations, published in his *Mycological Notes*, has succeeded in making clear the characters upon which most of the older species have been based.

Artificial Key to Species.

Spores perfectly smooth ..... 8. *T. poculatum.*
Spores finely but distinctly verruculose.
  Mouth definite, tubular, entire.
    Peridium smooth, or almost so ..... 2. *T. albicans.*
    Peridium pubescent ..... 1. *T. pubescens.*
  Mouth definite, fibrillose ..... 9. *T. minutum.*
Spores strongly verrucose or verrucose-echinulate.
  Mouth definite, tubular, entire.
    Peridium uncoloured (dingy white or pallid tan).
      Peridium smooth.
        Spores under 10 μ ..... 3. *T. McAlpinianum.*
        Spores over 10 μ ..... 4. *T. macrosporum.*
      Peridium rough with adhering exoperidium ..... 5. *T. adhaerens.*
    Peridium coloured.
      Peridium chestnut-brown ..... 6. *T. brumale.*
      Peridium chocolate-brown ..... 7. *T. Purpusii.*
  Mouth definite, fibrillose.
    Spores closely and finely verrucose ..... 10. *T. subfuscum.*
    Spores striate ..... 11. *T. striatum.*
  Mouth indefinite ..... 12. *T. australianum.*

SECTION I: Mouth definite; circular or elliptical, tubular or plane.

a. Spores finely and distinctly verruculose.

1. TULOSTOMA PUBESCENS, n. sp. Plate xxxiii, fig. 1.

Peridium depressed-globose, up to 10 mm. high, 20 mm. diam.; exoperidium persistent, dingy brown, almost black, in the nature of coarse mycelial fibres mixed with vegetable debris; endoperidium ferruginous, pubescent with closely appressed silky threads. Mouth definite, 2.5-3 mm. diam., circular, plane.

Stipe up to 4 cm. $\times$ 6 mm., equal, densely pubescent, colour of the peridium, stuffed, rugulose.

Gleba reddish-brown; capillitium hyaline, threads sparingly septate, slightly thicker than the spores, branched, septa plane. Spores globose or subglobose,

4-5.5 μ, apiculate; epispore finely and delicately verruculose, pallid ferruginous, 0.75 μ thick.

Habitat.—Solitary on the ground.

Distribution.—South Australia: Pt. Gawler (Apr., 1923, J. B. Cleland). Type in Herb. Cleland.

It is with some hesitation that the writer has erected this species, for it is based on a single specimen. Nevertheless, the plant is so characteristic that it may readily be recognized. The plane definite mouth, adhering fibrous exoperidium, pubescent endoperidium and stipe are very distinctive, for certain of these characters have been met with only in this specimen. The plant is somewhat damaged, hence the shape of the peridium, as shown in the photograph, is not characteristic.

2. TULOSTOMA ALBICANS White. Plate xxxiii, fig. 2; Pl. xxxv, fig. 19.

Bull. Torrey Bot. Club, vol. 28, 1901, p. 428.

Peridium depressed-globose, up to 10 mm. high, 12 mm. diam.; exoperidium soon falling away from the upper portion but persisting at the base of the endoperidium, which is smooth, thin, papyraceous, dingy-white or pallid-tan. Mouth small, 1 mm. diam., circular, short-tubular, entire.

Stipe 2-4 cm. × 3-6 mm., equal, bay-brown, finely striate, fibrillose, stuffed, with a small mycelial pad at the base.

Gleba reddish-brown; capillitium hyaline or tinted, threads branched, sparsely septate, septa moderately swollen. Spores globose or subglobose, 4-6 μ diam., frequently apiculate; epispore pallid ferruginous, finely and moderately verruculose, 1 μ thick.

Habitat.—Solitary or gregarious on the ground.

Distribution.—North America; Australia.

New South Wales: Dubbo (Oct., 1913. †J.B.C.), *Forbes (Aug., 1915. J.B.C.), Manildra (Oct., 1916. J.B.C.), *Near Barellan (Aug., 1918. J.B.C.), Narrabri (May, 1919. J.B.C.).

South Australia: *Reynella (July, 1914. J.B.C.; *Id.*, Lloyd, No. 80, as *T. McAlpinianum*), **Monarto South (J.B.C.), ***Beaumont, Adelaide (June, 1917. J.B.C.), between sand dunes and Milton Railway Station (Jan., 1920. Prof. Howchin), Berri (Jan., 1921. J.B.C.; *Id.*, Lloyd, No. 750, as *T. simulans*), Beaumont (July, 1921. J.B.C.), 10 miles west Overland Corner (Feb., 1922. J.B.C.), Big Swamp, 12 miles west Port Lincoln (Feb., 1922. J.B.C.), Ooldea (Aug., 1922. J.B.C.), Flinders Range, Pt. Augusta (Aug., 1922. J.B.C.), Mr. Zeitz Coll.

Victoria: Melbourne (June, 1885. F. M. Reader), near Dimboola (July, 1890. F. M. Reader).

Tasmania: Domain, Hobart (Mar., 1920. L. Rodway).

Var. NIGROSTIUM, n. var.

Peridium similar to *T. albicans*, but differing in that the mouth is strongly coloured, usually brown, frequently lead colour. Other characters as above.

Distribution.—New South Wales: Bumberry (Sept., 1916. J.B.C.), The Rock (July, 1917. J.B.C.; *Id.*, Lloyd, No. 382, as *T. albicans*).

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* These forms possess spores more strongly marked than the usual.

** This is a larger and more globose form.

*** Doubtful determination as the mouth is gone.

† J.B.C. = J. B. Cleland.

T. albicans is characterized by the pallid peridium, definite tubular mouth, and especially by the finely verruculose spores.

Lloyd has placed one of these collections under *T. McAlpinianum*, another under *T. simulans* Lloyd, and a third under *T. australianum*. It is difficult to separate *T. McAlpinianum* from this species, other than by the spore markings (see note under this species). In his paper Lloyd (1906) considers *T. simulans* to be a form of *T. mammosum* (*T. brumale*). The characters of this latter are the coloured peridium, darker mouth, freely septate capillitium and strongly verrucose spores. His *T. brevipes* he claims to be an uncoloured form, possessing all other characters; but his *T. simulans* is claimed to have a differently coloured peridium and different capillitium. If so, then it has no relationships with *T. brumale* whatsoever. The specimen so named in the collection from Berri, South Australia, is typically *T. albicans*, and does not differ in any particular, so far as the writer is able to judge.

T. albicans is the most abundant species in Australasia, judging from the collections that have passed through the writer's hands.

b. Spores strongly verrucose or verrucose-echinulate.

3. TULOSTOMA MCALPINIANUM Lloyd. Plate xxxiii, figs. 3, 4.

Tylostomeae, 1906, p. 15. (Emended).

Peridium depressed-globose or globose, up to 12 mm. high, 15 mm. diam.; exoperidium soon falling away from the upper portion, but remaining at the base of the endoperidium as a thickened, closely adherent disc; endoperidium smooth, partly covered with adhering particles of the exoperidium, or slightly pitted, papyraceous, dingy-white or pallid-tan. Mouth small, 1-1.5 mm. diam., circular or elliptical, short-tubular, entire.

Stipe 2-8 cm. × 3-5 mm., equal, slightly or not thickened basally, coloured bay- or chestnut-brown, fibrillose, striate, woody, stuffed.

Gleba reddish-brown; capillitium hyaline or tinted, threads sparingly branched, sparsely septate, septa slightly swollen. Spores globose or subglobose, 5-8 μ diam.; epispore pallid ferruginous, coarsely, bluntly and sparsely verrucose, 1 μ thick.

Habitat.—Solitary or gregarious on the ground.

Distribution.—New South Wales: Narrabri (June, 1918. J.B.C.). South Australia: River Murray, near Morgan (Nov., 1913. J.B.C.), Adelaide (July, 1920. J.B.C.; *Id.*, Lloyd, No. 710, as above), Kinchina (July, 1922. J.B.C.). Victoria: Canterbury (March, 1909. C. French, Jr.), Melton (Sept., 1899. C. French, Jr.).

The writer has found it impossible to separate this species from the preceding, save by the spore markings. It is evident that Lloyd himself is not clear as to the characters of this species, for he states (1906): "While it is very difficult to draw up a diagnosis of the differences between this and *T. albicans*, the plants are not the same and our photograph will show it better than our description can. The plant in general appearance very much resembles *T. mammosum*, but is uncoloured and has almost smooth spores. *T. albicans* belongs to a different type of plants in shape and cortex from *T. mammosum*." Further evidence as to the difficulty Lloyd has had in placing his species, is shown from his determinations of some of Dr. Cleland's specimens. For example, one collection (No. 80) which he has determined as being *T. McAlpinianum*, the writer places under *T. albicans*, for the spores are quite different from those of the collection (No. 710) Lloyd placed under *T. McAlpinianum*. A third collection (No. 79) Lloyd claimed to be this species has spores which are coarsely echinulate and fully twice as large.

In his original description of *T. McAlpinianum*, Lloyd stated that the spores were almost smooth, yet three collections named by him as this species have verrucose spores. Such confusion can occur only when species are erected on such variable characters as colour, shape and markings of the peridium. As three collections with verrucose spores have been determined by Lloyd as being *T. McAlpinianum*, the writer has arbitrarily fixed upon this as being the only character of specific value upon which it may be separated from *T. albicans*, for it is obvious that until some such stand is taken no means exists of determining this species accurately. See also remarks under *T. albicans*.

4. TULOSTOMA MACROSPORUM, n. sp. Plate xxxiii, fig. 5; Pl. xxxv, fig. 20.

Peridium depressed-globose, up to 8 mm. high, 12 mm. diam.; exoperidium completely falling away from the endoperidium, leaving this smooth save at the base; endoperidium white, smooth, thin, papyraceous. Mouth entire, short-tubular, circular, 1 mm. diam.

Stipe 2-3 cm. × 1.5-2 mm., equal, smooth, sparsely striate, woody, stuffed, slightly dilated at the base.

Gleba pallid-violaceous; capillitium tinted or hyaline, threads sparsely branched, septa slightly swollen. Spores globose or subglobose, 9-13 μ diam.; epispore ferruginous, densely and coarsely echinulate, spines about 1 μ long, epispore 1.5-2 μ thick.

Habitat.—Caespitose on the ground.

Distribution.—New South Wales: Dubbo (July, 1915. J.B.C.). Type in Herb. Clel. (*Id.*, Lloyd, No. 79, as *T. McAlpinianum*).

The caespitose habit, violaceous gleba, and especially the large and coarsely echinulate spores, characterize this species. If *T. McAlpinianum* is to be maintained as a species—separable only upon spore markings—then the above also must be considered a distinct and clearly defined species.

5. TULOSTOMA ADHAERENS Lloyd. Plate xxxiii, fig. 6; Pl. xxxiv, fig. 7.
Mycological Notes, vol. 7, 1923, p. 1199.

Peridium depressed-globose, up to 10 mm. high, 15 mm. diam.; exoperidium a firm, closely adhering sand case, bay-brown, rough; endoperidium dark-brown, tough, membranous. Mouth definite, elliptical, about 3 × 1 mm., entire, not or slightly protruding.

Stipe 2-3 cm. × 3-5 mm., fibrillose, ochraceous or bay-brown, woody, stuffed, equal, geniculate, with a slight mycelial bulb at base.

Gleba ochraceous or pallid-ferruginous; capillitium subhyaline, threads branched, slightly swollen at the septa. Spores globose or subglobose, 5-6 μ diam.; epispore pallid-ferruginous, closely and finely verrucose, 0.75 μ thick.

Habitat.—On the ground.

Distribution.—New South Wales: Narrabeen (July, 1916. J.B.C.). Type Coll. in Herb. Clel. (Lloyd, No. 794).

The above description has been drawn up from type collection material kindly donated by Dr. Cleland, and now in my herbarium, No. 2192.

Lloyd states that this is the first collection made in Australia possessing this type of mouth. He places it (1906) in Section 6 defined as "Mouth definite, naked, elongated, sometimes several on the same peridium."

The elongate plane mouth and rough adhering exoperidium characterize the species. As to whether this last feature is constant, or merely a condition due to immaturity of the plants, it is impossible to determine from the material at hand.

6. TULOSTOMA BRUMALE Persoon. Plate xxxiv, fig. 8; Pl. xxxv, fig. 21.

Syn. Meth. Fungi, 1801, p. 139.—*Tulostoma mammosum* Fr., *Syst. Myc.*, vol. 3, 1829, p. 42.—*Tylostoma pedunculatum* Schroet., Cohn, *Beitr. Biol. Pflan.*, vol. 2, 1877, p. 65.

Peridium globose or slightly depressed-globose, up to 12 mm. diam.; exoperidium usually completely falling away from all but the base of the endoperidium, occasionally persisting as irregular, scattered patches; endoperidium papyraceous, chestnut- or bay-brown, smooth. Mouth small, 1-1.5 mm. diam., circular, short-tubular, entire, protruding, darker than the endoperidium.

Stipe 2-4 cm. × 2-4 mm., bay- or reddish-brown, equal, smooth or slightly scaly, sparingly striate, stuffed, with a small mycelial bulb at the base.

Gleba ferruginous; capillitium hyaline, threads branched, somewhat freely septate, septa moderately swollen; spores globose, 4-5 μ diam., frequently apiculate; epispore pallid-ferruginous, moderately and sparsely verrucose, 1 μ thick.

Habitat.—Solitary on the ground.

Distribution.—England; Northern and Central Europe; North America; Australia; New Zealand.

Victoria: Frankston (July, 1905. D. McAlpine; *Id.*, Lloyd, No. 23, as *T. albicans*).

New Zealand: Sandhills, Levin, Wellington (Dec., 1919. E. H. Atkinson).

Lloyd states (1905) that there is one collection of this species from Australia at Kew, collected at White River in 1870, which he believes to be the typical form. On the other hand, he claims that the true form does not occur in North America, and lists (1906) under *T. simile* and *T. rufum* Lloyd, all forms found in that country.

The New Zealand and Australian specimens listed above agree in all particulars with recent descriptions, although some forms approach *T. Purpusii* in the colour of the endoperidium, lending strength to the contention that the latter is better considered as a variety of *T. brumale*. One recent worker (Rea, 1922) describes the spores as being "pinkish". Surely this is an unusual colour for the spores of any species belonging to this genus. If correct, then our form is not the same as the European, as the spores are decidedly ferruginous, and under the microscope, pallid-ferruginous, when viewed with apochromats, which render colour tones correctly.

7. TULOSTOMA PURPUSII P. Hennings. Plate xxxiv, fig. 9.

Hedwigia, vol. 37, 1898, p. 274.

Peridium depressed-globose, up to 15 mm. high, 2 cm. diam.; exoperidium imperfectly falling away from the endoperidium, remaining as small, irregular patches upon the upper surface and firmly attached basally; endoperidium dark-chestnut, chocolate or sepia-coloured, thin, firm, membranous, frequently furfuraceous. Mouth small, 1-2 mm. diam., circular or elliptical, short-tubular, entire, frequently darker in colour.

Stipe 1.5-2 cm. × 3-5 mm., equal, ochraceous or ferruginous, floccose but not scaly, sparsely striate, stuffed, often slightly inflated basally.

Gleba ferruginous; capillitium tinted or hyaline, threads sparingly branched, scantily septate, septa slightly swollen. Spores globose or subglobose, 5-7 μ diam.; epispore pallid-ferruginous, moderately and somewhat closely verrucose, 1 μ thick.

Habitat.—Solitary or caespitose on the ground.

Distribution.—North America; Australia.

New South Wales: Under pine tree, Botanic Gardens, Sydney (June, 1908. E. Cheel; *Id.* by Lloyd as above); specimens in Herb. Cleland. Garden, Neutral Bay, Sydney (Dec., 1919. J.B.C.).

The writer is of the opinion that this is best considered as a large, more deeply coloured form of *T. brumale*, for it is difficult to separate it from this species other than upon these two characters. Lloyd states (1906): "This species can easily be taken for a giant form of *T. mammosum*. It is a rare plant and I have seen from America only the type specimens at Berlin, which were collected in Colorado by a Mr. Purpus. We refer here (for the time at least, rather than make a new species) plants from Australia with the same general characters, but which differ in the more persistent cortex and the spores, which in the Australian species vary from 4 to 7 μ."

SECTION II.—Mouth definite, fibrillose.

a. Spores perfectly smooth.

8. TULOSTOMA POCULATUM White. Plate xxxiv, figs. 10, 11; Pl. xxxv, fig. 22.
Bull. Torrey Bot. Club, vol. 28, 1901, p. 431.

Peridium depressed-globose, up to 10 mm. high, 12 mm. diam.; exoperidium breaking away completely save the persistent basal portion; endoperidium fawn-coloured or dingy-white, smooth, papyraceous. Mouth raised, surrounded by a circular fibrillose zone which may attain a diameter of 3 mm.

Stipe 2-3 cm. × 3-5 mm., tan-coloured, sulcate, striate, equal, stuffed, slightly bulbous at the base.

Gleba ferruginous; capillitium tinted or hyaline, threads sparingly branched, slightly swollen at septa. Spores globose or subglobose, frequently subangular, 4-6 μ diam., apiculate; epispore pallid-ferruginous, perfectly smooth, 0.75 μ thick.

Habitat.—Solitary or gregarious on the ground.

Distribution.—North America; Australia; New Zealand.

New South Wales: Belmore, Sydney (July, 1909. A. A. Hamilton), The Rock (July, 1917. J.B.C.; *Id.*, Lloyd, No. 381, as above), Coolamon (May, 1918. J.B.C.), near Barellan (Aug., 1918. J.B.C.), * Wombeyan Caves (Nov., 1919. J.B.C.).

South Australia: Beaumont, Adelaide (May, 1920. J.B.C.), * Kinchina (July, 1922. J.B.C.).

New Zealand: Sandhills, Levin, Wellington (Nov., 1919. S. A. Cunningham, E. H. Atkinson, G.H.C.; *Id.*, Lloyd, No. 67, as above).

This species is characterized by the pallid, smooth peridium, fibrillose, raised mouth and smooth, apiculate spores. The smooth spores especially are a constant character of all the specimens listed above.

b. Spores finely and distinctly verruculose.

9. TULOSTOMA MINUTUM White.
Bull. Torrey Bot. Club, vol. 28, 1901, p. 430.

Peridium depressed-globose, 0.5-1 cm. high, 1-1.2 cm. diam.; exoperidium dingy-brown, imperfectly breaking away from the upper part of the endoperidium, but remaining at base; endoperidium pallid-chestnut-brown, membranous. Mouth slightly raised, fibrillose, small, 2 mm. diam.

Stipe 1-2 cm. × 2-4 mm., slender, stuffed, brown, striate, frequently with small mycelial pad at base.

* Doubtful determinations; mouths gone, but spores *T. poculatum* type.

Gleba ferruginous; capillitium tinted, threads sparingly branched, septa slightly swollen. Spores globose or subglobose, 4-6 μ diam., apiculate; epispore ferruginous, minutely and closely verruculose, 1 μ thick.

Habitat.—Solitary on the ground.

Distribution.—North America; Australia.

South Australia: Berri (Jan., 1921. J.B.C.), Beaumont, Adelaide (July, 1921. J.B.C.).

These specimens are doubtfully referred to *T. minutum* White. They are too small to be referred to other species possessing fibrillose mouths, with the exception of *T. poculatum*, and differ from this species in the spores being closely and finely verruculose and not smooth.

c. Spores verrucose.

10. Tulostoma subfuscum White. Plate xxxiv, fig. 12; Pl. xxxv, fig. 18.
Bull. Torrey Bot. Club, vol. 28, 1901, p. 433.

Peridium depressed-globose, up to 12 mm. high, 15 mm. diam.; exoperidium dingy-brown, imperfectly breaking away from apical portion, but remaining as a firm membrane at the base of the endoperidium; the latter smooth, varying in colour from bay-brown to dingy-ferruginous, tough, membranous. Mouth raised, minute, surrounded by a scanty fibrillose zone 1-2 mm. diam.

Stipe 2-3 cm. × 2-3 mm., fibrillose or scaly, leathery, dingy-brown, striate, equal, stuffed, with small mycelial bulb at base.

Gleba ferruginous; capillitium hyaline or tinted, threads branched, sparsely septate, slightly thickened at the septa. Spores globose to subglobose, 4-6 μ diam., sometimes apiculate; epispore pallid-ferruginous, finely and moderately verrucose, 0.75 μ thick.

Habitat.—Solitary or gregarious on the ground.

Distribution.—North America; Australia.

New South Wales: Mummulgum (Dec., 1916. J.B.C.; *Id.*, Lloyd, No. 267, as *T. poculatum*).

This species differs from *T. poculatum* in the somewhat larger size, darker colour of the peridium and stipe, smaller and less fibrillose mouth and finely verrucose spores. Lloyd (1906) considers it to be a form only, but it is quite a distinct plant. The colour of the peridium varies from dark-brown (almost chocolate) to bay-brown, but as colour has little specific value, this variation is of little moment.

11. Tulostoma striatum, n.sp. Plate xxxiv, fig. 13; Pl. xxxv, fig. 17.

Peridium depressed-globose, up to 15 mm. high, 20 mm. diam.; exoperidium pallid-tan colour, soon falling away save where persistent at the base, in some specimens persisting as irregular roughened patches; endoperidium pallid-tan or dingy-white, smooth, papyraceous. Mouth raised, irregularly circular, surrounded by a fibrillose zone, up to 3 mm. diam.

Stipe 2-6 cm. × 2-4 mm., equal, pallid-tan, stuffed, striate, slightly enlarged towards the base.

Gleba ferruginous; capillitium hyaline, threads somewhat flattened, branched, sparingly septate, slightly swollen at the septa. Spores globose or subglobose, 4-6 μ diam.; epispore coarsely and sparsely verrucose, verrucae arranged in striae, 1 μ thick.

Habitat.—Solitary or caespitose on the ground.

Distribution.—New South Wales: Forbes (Aug., 1915. J.B.C.; *Id.*, Lloyd, No. 81, as *T. poculatum*). South Australia: Berri (Jan., 1921. J.B.C.; *Id.*,

Lloyd, No. 751, as *T. poculatum*. Type); Ooldea (Aug., 1922. J.B.C., two collections), Unknown locality (J. G. O. Tepper; *Id.*, Lloyd, No. 14, as *T. australianum* . Specimens in Herb. Victorian Dept. Agr.).

This species resembles *T. poculatum* in mouth characters, but is a much larger plant, and in addition possesses verrucose spores. The verrucae are arranged in striae, giving the spores a very characteristic appearance, and it is upon this character that the species is erected. It somewhat resembles the description of *T. tuberculatum* White, but as there is no mention of these peculiar and characteristic spore striae in the description, it is considered to be distinct and so kept separate.

Section III. Mouth indefinite.

12. Tulostoma australianum Lloyd. Plate xxxv, figs. 14-16.

Tylostomeae, 1906, p. 20 (Emended).

Peridium strongly depressed-globose, almost pulvinate, up to 15 mm. high, 24 mm. diam.; exoperidium falling completely away save at the base; endoperidium smooth, dingy-white, tough, thick, membranous. Mouth indefinite, plane, a simple, irregularly torn aperture.

Stipe up to 15 cm. × 6 mm., equal, covered with coarse deciduous scales, markedly striate, woody, stuffed, bay-brown, with a strongly developed woody bulbous base.

Gleba ferruginous; capillitium hyaline, threads branched, moderately swollen at the somewhat sparse septa. Spores globose or subglobose, 4-6 μ diam.; epispore finely and sparsely verrucose, pallid-ferruginous, 0.75 μ thick.

Habitat.—Solitary on the ground.

Distribution.—South Australia: Monarto South (May, 1921. J.B.C. Two collections, both *Id.*, Lloyd, Nos. 792, 781, as above), same locality (Sept., 1921. J.B.C.; *Id.*, Lloyd, No. 793, as above).

This species is characterized by the indefinite plane mouth, scaly stipe and verrucose spores. In his original description Lloyd states that the spores are smooth, and the stipe is not scaly. He further mentions that the species is the most abundant in Australia. "It has a large head and a short stipe, and in general appearance is the same as *T. album* (type specimen at Kew), but it has smooth spores (slightly granular in *T. album*)." Thus his original conception of the species was a plant with a non-scaly stipe and smooth spores. Nevertheless, he has determined no less than three collections of the plant described above as being *T. australianum*. Rather than erect another species, the writer has emended Lloyd's description to include these collections. Lloyd has also determined as *T. australianum* one collection (Dept. Agr. Vic. Coll., No. 14) which the writer places under *T. striatum*. Another the writer places under *T. albicans*.

Lloyd (1906) lists two additional species under this section. As the writer has not seen specimens, he cannot pass an opinion as to their validity, so gives Lloyd's descriptions to enable the student to place them.

Tulostoma Readeri Lloyd.

Tylostomeae, 1906, p. 21.

Peridium uncoloured, firm, white. Cortex of the nature of a sand case, peeling off imperfectly and persistent at the base. Mouth an enlarged torn opening. Stipe long, dark, rough but not scaly, frequently with mycelial fibres. Capillitium hyaline, broad threads. Septa rare with rounded ends and not swollen. Spores 5-6 μ, granular.

This plant has a general resemblance to *T. granulosum*, but has not the same mouth. Species collected by F. M. Reader at Casterton, Australia.

TULOSTOMA EGRANULOSUM Lloyd.
Tylostomeae, 1906, p. 21.

Peridium uncoloured, with an irregular, torn aperture. Cortex as a sand case imperfectly separating, thickened and persistent at the base. The cortex does not separate as freely as most species, but adheres with a "pitted" effect on the peridium. Stipe dark, rigid. Capillitium subhyaline, with rare but swollen nodes. Spores 5-6 μ, granular.

This plant is very close to *T. granulosum* of Europe, but the mouths of these specimens are not furnished with "granular fibrils." Australia: D. McAlpine, F. M. Reader.

In Cooke's *Handbook of Australian Fungi*, 1894, pp. 224-225, the following species are recorded as being found in Australia. Judging from the descriptions, one is led to believe that the whole were compiled from Saccardo's *Sylloge Fungorum*, vol. 7.

a. TULOSTOMA ALBUM Massee, *Grevillea*, vol. 19, 1891, p. 95. Lloyd states (1905) that: "The specimen on which this is based is old, weathered and bleached out. It has a large head and a short thick stalk, but I could not make out its mouth characters." It is therefore impossible to place this species, for in the original description no mention is made of its mouth characters.

b. TULOSTOMA GRANULOSUM Lev., *Demid. Voy.*. Vol. 2, 1842, p. 120, t. iv, fig. 1—*Tulostoma brachypus* Czern., *Bull. Mosc.*, 1845, p. 144.—The description is too inadequate to allow of this species being placed.

c. TULOSTOMA FIMBRIATUM Fr., *Syst. Myc.* vol. 3, 1829, p. 43.—It is probable that this is a misdetermination of *T. poculatum*, for no species with "fimbriate" mouths is known to have been collected in Australia. Lloyd (1905) states that there are specimens at Kew from Swan River so labelled, but he was unable to examine their mouths.

d. TULOSTOMA LEPROSUM Kalchbr., *Grev.*, vol. 4, 1876, p. 72.—This is referred to *T. mammosum* by Kalchbrenner, but is separated on account of the peridium being covered with a "lurid umber mealy scurf." The description is too imperfect to allow of its being recognized.

e. TULOSTOMA MAMMOSUM Fr.—This is a synonym of *T. brumale* Pers. (q.v.).

f. TULOSTOMA MAXIMUM Cooke and Massee, *Grev.*, vol. 15, 1887, p. 94.—Lloyd, who has examined the type at Kew, states that this is a synonym of *Chlamydopus Meyenianus* (Kl.) Lloyd, *Letter*, No. 67, 1918, p. 12.

g. TULOSTOMA PULCHELLUM Saccardo, *Bull. Soc. Myc. Fr.*, vol. 5, 1889, p. 118.—"This species . . . rests on a single little specimen . . . made in Australia by Tepper. While it is not fair to form an opinion of a 'species' on one little specimen, this must form a section by itself. The very short stem is itself a departure from all others and the stem does not appear to be inserted in a socket as in all other true Tylostomas. The colour is now chocolate brown, the surface, under a lens, scurfy. The mouth is simply an indefinite opening. Gleba, rust colour. Spores, unusually large for a Tylostoma, 8-9 μ, globose, pale coloured, smooth [5-6 μ, according to Saccardo]." Lloyd, *Myc. Notes*, vol. 7, 1923, p. 1233.—The species is said to grow upon branches.

h. TULOSTOMA WIGHTII Berkeley, *Hook. Jour. Bot.*, 1842, p. 157.—The species was described from specimens collected in India. No specimens from Australia are at Kew.

Literature Cited.

BESSEY, C. E., 1887.—Growth of *Tulostoma mammosum*. *American Naturalist*, vol. 21, p. 665.

CLELAND, J. B., and CHEEL, E., 1916.—Notes on Australian Fungi. III. Nidulariaceae and Lycoperdaceae. *Journ. Roy. Soc. N.S.W.*, vol. 50, pp. 105-129.

COOKE, M. C., 1892.—*Handbook of Australian Fungi*, 457 pp. London.

FISCHER, ED., 1900.—Plectobasidiineae, in Engler and Prantl, *Naturlichen Pflanzenfamilien*, I**, pp. 329-346.

LLOYD, C. G., 1905.—*The Lycoperdaceae of Australia, New Zealand and Neighboring Islands*. 44 pp. Cincinnati.

————, 1906.—*The Tylostomeae*. 28 pp. Cincinnati.

REA, CARLETON, 1922.—*British Basidiomycetae*. 799 pp. Cambridge.

SCHROETER, J., 1887.—Ueber die Entwickelung und die systematische Stellung von Tulostoma Pers., Cohn's *Beitrage zur Biologie der Pflanzen*, Bd. 2, p. 65.

TONI, J. B. DE, 1888.—Lycoperdaceae, in Saccardo's *Sylloge Fungorum*, vol. 7, pp. 48-154.

WHITE, MISS V. S., 1901.—The Tylostomaceae of North America, *Bull. Torrey Bot. Club*, vol. 28, pp. 421-444.

EXPLANATION OF PLATES XXXIII-XXXV.

Plate xxxiii.

1. *Tulostoma pubescens* G. H. Cunn. × 5/4. This plant is much broken and so is not accurately represented in the photograph.
2. *Tulostoma albicans* White. Natural size.
3. *Tulostoma McAlpinianum* Lloyd. Natural size.
4. *Tulostoma McAlpinianum* Lloyd. × 3/2. Peridium, showing structure of the definite, tubular mouth.
5. *Tulostoma macrosporum* G. H. Cunn. Natural size. Note the caespitose habit. Three peridia are joined together in the specimen on the right; the stipes have been broken away.
6. *Tulostoma adhaerens* Lloyd. Natural size.

Plate xxxiv.

7. *Tulostoma adhaerens* Lloyd. × 2. Peridium showing definite, elliptical, almost plane mouth.
8. *Tulostoma brumale* Pers. Natural size.
9. *Tulostoma Purpusii* P. Henn. Natural size. Specimen on the right has lost its stipe.
10. *Tulostoma poculatum* White. Natural size. Peridium in centre (lower) is inverted to show stipe socket.
11. *Tulostoma poculatum* White. × 2. Peridia showing fibrillose mouths; weathered specimen on the left.
12. *Tulostoma subfuscum* White. Natural size.
13. *Tulostoma striatum* G. H. Cunn. Natural size.

Plate xxxv.

14. *Tulostoma australianum* Lloyd. × 3/4.
15. *Tulostoma australianum* Lloyd. Natural size.
16. *Tulostoma australianum* Lloyd. × 3/2. Peridium showing the indefinite mouth.
17. *Tulostoma striatum* G. H. Cunn. Spores. Note striae on the surface of the epispore.
18. *Tulostoma subfuscum* White. Spores. Note rounded sparse verrucae on the epispore.
19. *Tulostoma albicans* White. Spores. Note verruculose surface of the epispore.
20. *Tulostoma macrosporum* G. H. Cunn. Spores. Note large size of the spores and their rough surfaces.
21. *Tulostoma brumale* Pers. Spores. Note verrucose nature of the epispore.
22. *Tulostoma poculatum* White. Spores. Note that spores are smooth and irregular in shape.

All photographs were taken by H. Drake. Photomicrographs magnified 540 diam. The photomicrographs were taken with a 4 mm. apochromatic objective, N.A. 0.7, comp. ocular × 10, 200 mm. tube length; Watson's parachromatic condenser, yellow-green screen, filament lamp, × 540, exposure 2 minutes.